



This is a postprint of:

Loss of technological leadership of rentier economies, a two country endogenous growth model

T.C.M.J. van de Klundert & J.A. Smulders

Journal of International Economics, 2001, vol. 54, nr. 1, pp. 211-231

For citation:

Please use the reference above

Link to the postprint file:

<http://arno.uvt.nl/show.cgi?fid=14021>

More information about this publication:

<http://repository.uvt.nl/id/ir-uvt-nl:oai:wo.uvt.nl:84783>

Loss of Technological Leadership of Rentier Economies, a two-country endogenous growth model

Theo van de Klundert and Sjak Smulders*

CentER and Department of Economics, Tilburg University

Abstract History shows that rich countries may lose their productivity advantage by changing to a rentier economy with large investments abroad. In our two-country two-sector model with firm-specific knowledge and perfect international capital markets, the initially most productive country is being overtaken by the initially backward country. The two countries share the same structural parameters but have different initial knowledge stocks. The larger the initial productivity gap is, the larger is the leader's productivity loss, which implies path-dependency. The existence of a non-tradables sector drives the result. The leading economy gradually accumulates net foreign assets. Interest receipts are spent on imports and non-tradables. Labor is shifted from tradables production and research to non-tradables.

JEL codes: F12, F21, F43, O41

Key words: leapfrogging, productivity convergence, endogenous growth, international capital mobility, non-tradables.

*correspondence: Department of Economics, Tilburg University, P.O.Box 90153, 5000

LE Tilburg, The Netherlands; Ph. +31.13.466.2920, Fax: +31.13.466.3042, e-mail:

j.a.smulders@kub.nl

1. Introduction

History shows that economic leadership shifts from city to city or from country to country. Venice, the center of economic activity in the fifteenth century, was replaced by Antwerp, Antwerp by Genoa, and the latter by Amsterdam (Braudel 1986, p.34).

Maddison's (1991) data document that the Dutch Republic had highest GDP per capita in the seventeenth century, but was surpassed by the UK in the early nineteenth century.

The US in turn became the leading nation around 1900.

In the stories of success and demise of these places, the loss of leadership is often accompanied by a change to a rentier economy. While productivity was outperformed by the "nouveaux riches", the formerly leading nations remained rich, at least for a long time, they were investing their funds abroad and spending affluently on imported luxuries, on local residential construction, performing arts, and on other non-tradables.¹ The flow of capital from the Dutch republic to Britain in the eighteenth century is well documented by Brezis (1995). The UK became a net lender in the period from 1820 till 1870. Britain was lending all over the world, in particular to the US. From being a borrower in the nineteenth century, the US became a lender in the twentieth century (Williamson 1964).

Concepts from growth theory help to explain why loss of leadership and capital outflows occurred simultaneously. Lagging countries may catch up by imitating the leading countries (Abramovitz 1986). Imitation implies high rates of return which attract funds from the leading countries where costly innovation has to drive growth. The catch-up process is likely to stop once productivity levels have converged. To explain overtaking, the initially backward country must have -- or acquire -- some advantage over

the initially leading country. Scale economies might help a large backward country to overtake a small leading country (as in Van Elkan, 1996; Barro and Sala-i-Martin, 1997). However, from an empirical perspective, the relevance of scale effects is often disputed. Alternatively, the backward country may acquire an advantage over the leading country if it adopts technologies with higher potential, while the leading country sticks to existing technologies. Brezis, Krugman and Tsiddon (1993) have coined this phenomenon technological leapfrogging.

In this paper, overtaking is explained by the interaction between capital mobility, imperfect international spillovers, and non-tradables consumption. We develop a general equilibrium two-country endogenous growth model with perfect capital mobility. The backward country, which has a relatively low initial stock of knowledge, benefits more from foreign technology spillovers than the leading country and realizes a higher (ex-ante) rate of return in innovation. This attracts capital from the leading country. Revenues from foreign investment boost consumption of both tradables and non-tradables in the leader country. Whereas tradables can be imported, the rise in consumption of non-tradables leads to a reallocation of productive resources towards the non-tradables sector. This implies a shift away from the more dynamic open sector, thus hurting productivity growth. Despite the fact that the two countries share the same structural parameters, the steady state is asymmetric: the initially more productive economy ends up with a positive net foreign asset position and a larger non-tradables sector, at the cost of lower productivity than the initially lagging economy.

By explicitly addressing traded and non-traded goods as well as capital mobility, our analysis contributes to three strands of literature on growth in open economies. First, a related literature deals with convergence and capital mobility. In models with constant

returns to scale, perfect international financial capital mobility and a single tradable consumption good, long-run productivity levels and growth rates converge across countries. Introduction of adjustment costs in the accumulation of reproducible factors of production (cf. Turnovsky and Sen, 1991) or of a borrowing constraint with respect to human capital accumulation (cf. Barro, Mankiw and Sala-i-Martin, 1995) retards the convergence of backward economies but does not change the convergence property. We contribute to this literature by exploring the role of non-tradables, by endogenizing growth, and applying a two-country framework.

A second strand of literature focuses on technological leapfrogging. In Brezis, Krugman and Tsiddon (1993) the lagging country has low wages which makes it easier to cope with the initial inefficiencies of a new technology. If this new technology has a higher learning-by-doing potential than the existing technology, the backward country is going to leapfrog the leader. Brezis and Tsiddon (1998) show in a similar model that capital mobility may spur leapfrogging. Leapfrogging models share two main assumptions: first, technological learning is localized and, second, major breakthroughs in technology arise infrequently and exogenously. In the two models just mentioned, growth is driven by country-specific learning by doing. In Ohyama and Jones (1995), learning is firm-specific. In our model, firms also rely on firm-specific (local) knowledge, which is augmented by investing in R&D along the lines set out in Romer (1990). This distinguishes our approach from leapfrogging models, since technology is entirely endogenous and our leapfrogging result does not require an exogenous jump in available technology.

Labor applied in R&D has an alternative use in the production of non-traded consumption goods in our model. The combination of these assumptions implies that

economic development is to some extent localized or, to use another term, home-bound.² Home-bound activities are also introduced in Buiter and Kletzer (1993). In their model, a non-traded capital good (“human capital”) is produced with a non-traded input in the form of labor time that has an alternative use as intrinsically valued leisure.³ Assuming constant returns with respect to the augmentable factors of production, they show that differences in savings behavior can influence long-run growth differentials across countries.

Third, capital mobility has been studied in a growth model based on R&D and trade by Grossman and Helpman (1991) and Feenstra (1996). They focus on the difference between knowledge either as a local public good or as an international public good and abstract from non-tradables. They find that if knowledge spillovers do not cross borders (so that knowledge is home-bound), growth rates may diverge. With perfect international knowledge spillovers, however, growth rates converge and symmetric countries that start from different initial conditions do not leapfrog in terms of productivity levels. In our model, we incorporate local as well as imperfect international knowledge spillovers: productivity in R&D depends on domestic and foreign knowledge stocks. Because of diminishing returns with respect to domestic knowledge, each country's own long-run growth rate converges to the foreign growth rate. Constant returns with respect to the world stocks of knowledge, however, causes this common long-run growth rate to be endogenous. Trade in financial assets not only results in leapfrogging but also has an impact on long-run growth. In this respect our model differs from the results obtained in Grossman and Helpman (1991, ch. 7). In their discussion of international knowledge spillovers trade in financial assets has no effect on long-run growth rates as non-traded goods are absent.

The outline of the rest of the paper is as follows. In Section 2 we present our model. Section 3 analyses the impact of foreign asset holdings on international productivity differentials and on the world growth rate. Section 4 studies the dynamics and determines foreign asset accumulation. In section 5 we briefly explore some welfare implications. Section 6 concludes. Technical details on dynamic aspects are considered in the appendices.

2. A two-country endogenous growth model

2.1. Overview of the model

We consider two countries with identical preferences, technological opportunities, and primary factor endowments. However, one country starts at a lower productivity level than the other country. Each country has one primary factor of production in fixed supply, labor, which is allocated over two sectors, tradables and non-tradables. Non-tradables are homogenous and supplied in a perfectly competitive market. Tradables are differentiated and each variety is produced by a single monopolistic firm. World trade is therefore characterized by monopolistic competition. Firms control and accumulate firm-specific knowledge (as in Smulders and Van de Klundert, 1995). Within each country, there is a continuum of symmetric firms on the unit interval. This allows us to save on notation by formulating the model for a single representative firm. There are no transport costs. Financial assets are internationally mobile so that interest parity holds.

When presenting the equations of the model, we denote countries by superscript i or j . All equations in the remainder of this section apply to both countries, $i = 1, 2$, and $j =$

1, 2 with $j \neq i$. All variables depend on the time index t , which is omitted where no ambiguity arises.

2.2. Consumers

Consumers have instantaneous Cobb-Douglas preferences over two types of goods,⁴ non-tradables C_Y , and tradables C_X . Tradables are differentiated and the elasticity of substitution between two varieties equals ε . Due to our assumption of symmetric firms and our normalization of the number of firms within a country to unity, only imported varieties M and consumption of home-produced tradables varieties D need to be distinguished. Intertemporal preferences are logarithmic and the utility discount rate equals ϑ .

$$U^i(0) = \int_0^{\infty} \ln C^i(t) e^{-\vartheta t} dt \quad (1)$$

$$C^i = (C_X^i)^{\sigma} (C_Y^i)^{1-\sigma} \quad (2)$$

$$C_X^i = \left[(D^i)^{(\varepsilon-1)/\varepsilon} + (M^i)^{(\varepsilon-1)/\varepsilon} \right]^{\varepsilon/(\varepsilon-1)} \quad (3)$$

Consumers maximize intertemporal utility over an infinite horizon. The decision problem consists of three stages subject to the usual budget constraints. In the first stage, each consumer decides on the path of aggregate consumption over time, given the price index of aggregate consumption p_c and the nominal interest rate in the world capital market r . This gives rise to the familiar Ramsey rule.

$$\dot{C}^i/C^i = r - \dot{p}_c^i/p_c^i - \theta . \quad (4)$$

The growth rate of consumption equals the difference between the real consumption rate of interest and the pure rate of time preference.

In the second stage total expenditure on consumption is divided over non-tradables and tradables. The fraction σ is spent on tradables, the remainder on non-tradables:

$$C_Y^i p_Y^i = (1-\sigma) C^i p_c^i \quad (5)$$

where the aggregate consumption price index is defined as:

$$p_c^i = \left(\frac{p_X}{\sigma} \right)^\sigma \left(\frac{p_Y^i}{1-\sigma} \right)^{1-\sigma} \quad (6)$$

In the third stage, total tradables consumption $C_X = \sigma C p_c/p_X$ is divided over domestically produced tradables varieties and foreign varieties, with prices p^i and p^j respectively. This stage yields the following demand equations:

$$D^i = [\sigma C^i p_c^i / p_X] \left(p^i / p_X \right)^{-\varepsilon} \quad (7)$$

$$M^i = [\sigma C^i p_c^i / p_X] \left(p^j / p_X \right)^{-\varepsilon} \quad (8)$$

where p_X is the price index for tradables, which is the same for both countries and is defined by:

$$p_X = \left[(p^i)^{1-\varepsilon} + (p^j)^{1-\varepsilon} \right]^{1/(1-\varepsilon)} \quad (9)$$

2.3. Firms

In the non-tradables sector, one unit of labor L_Y produces one unit of non-tradables Y .

Perfect competition prevails, so that the non-tradables price p_Y equals the wage w .

$$Y^i = L_Y^i \quad (10)$$

$$p_Y^i = w^i \quad (11)$$

In the tradables-sector, each monopolistic firm produces a volume X of its own product variety employing labor L_x with productivity h .

$$X^i = h^i L_x^i \quad (12)$$

Labor productivity h is to be interpreted as firm-specific knowledge that cannot be traded. Firms have to accumulate their own knowledge by allocating labor L_R to R&D activities. In this sense, knowledge in the tradables sector is home-bound. Moreover, knowledge cannot be fully appropriated: there are spillovers within each country and across borders. These ideas are formalized as follows:

$$h^i = \xi K^i L_R^i \quad (13)$$

$$\text{where } K^i \equiv (h^i)^{1-\alpha_h-\alpha_f} (\bar{h}^i)^{\alpha_h} (\bar{h}^j)^{\alpha_f}$$

The productivity of researchers depends on the scaling parameter ξ and the knowledge base K . The latter consists of three elements. First, firms build upon their own specific knowledge stock accumulated in the past. Second, all firms benefit from knowledge spillovers emanating from domestic firms. Third, there are knowledge spillovers from abroad. Knowledge spillovers relate to the average level of knowledge in the different economies, denoted by \bar{h} . Both types of spillovers are taken as given by each individual firm.

Firms maximize the present discounted value of profits by choosing output levels X and R&D intensity L_R . Each firm takes into account that it faces a downward sloping demand curve in the world market with elasticity ε . The macro-economic price levels p_X and p_c are conceived as given. The Hamiltonian corresponding to the maximization procedure for a firm in country i is:

$$H^i = \left[\sigma \left(C^i p_c^i + C^j p_c^j \right) p_X^{\varepsilon-1} / X^i \right]^{1/\varepsilon} X^i - w^i \left[X^i / h^i + L_R^i \right] + q^i \xi \left[(h^i)^{1-\alpha_h-\alpha_f} (\bar{h}^i)^{\alpha_h} (\bar{h}^j)^{\alpha_f} \right] L_R^i$$

where the first term in brackets is the firm's inverse demand curve derived from (7) and (8),⁵ the second term in brackets is the firm's labour requirement in production and research, see (12), and q is the co-state variable associated with (13), referred to as the shadow price of firm-specific knowledge. The first order conditions can be written as:

$$p^i = \frac{\varepsilon}{\varepsilon - 1} \frac{w^i}{h^i} \quad (14)$$

$$q^i = w^i / \xi K^i \quad (15)$$

$$p^i \left(\frac{\varepsilon - 1}{\varepsilon} \right) L_x^i + \xi (1 - \alpha_h - \alpha_f) \left(\frac{K^i}{h^i} \right) q^i L_R^i + \dot{q}^i = r^i q^i \quad (16)$$

Firms set a mark-up over marginal cost equal to $\varepsilon/(\varepsilon - 1)$. Labor demand for R&D follows from setting marginal revenue ($\xi K q$) equal to marginal cost (w). Firms face a trade-off with respect to investing in specific knowledge as appears from the arbitrage condition (16). This condition says that investing an amount of money equal to q in the capital market (the RHS of 16) should yield the same revenue as investing that same amount of money in knowledge creation. The latter raises labor productivity in the tradables sector and hence revenue in this sector (first term on the LHS of 16), it raises also the knowledge base in R&D (second term) and it yields a capital gain (last term).

Productivity levels in the tradables sector may differ across countries, but are identical across firms within a country. For this reason average knowledge levels are equal to the knowledge levels of firms in each country ($\bar{h}^i = h^i$). Taking this into account and substituting (14) and (15) into (16), we arrive at:

$$\xi (h^i / h^j)^{-\alpha_f} L_x^i + (1 - \alpha_h) \dot{h}^i / h^i - \alpha_f \dot{h}^j / h^j = r - \dot{p}^i / p^i. \quad (17)$$

This equation summarizes investment behavior in the economy. The LHS represents the rate of return on investment in R&D in country i , the RHS is the producers' real cost of capital. Note from the first term that because of international spillovers the lagging country (with $h^i / h^j < 1$) has a higher rate of return for given labor allocation L_x^i .

2.4. Market clearing

Markets for non-tradables clear, which implies $Y^i = C_Y^i$. Substituting (10), (5), (11) and (14), we may write this condition as:

$$L_Y^i = \frac{(1-\sigma)C^i p_c^i}{\left(\frac{\varepsilon-1}{\varepsilon}\right)h^i p^i} \quad (18)$$

More labor is employed in the non-tradables sector if real consumption is higher and if productivity in the tradables sector (h) is lower.

Markets for non-tradables clear, which implies $X^i = D^i + M^i$. Using (7) and (8) we find: $X^i/X^j = (p^i/p^j)^{-\varepsilon}$. After substituting (12) we may write this condition as:

$$\frac{p^i}{p^j} = \left(\frac{h^i L_x^i}{h^j L_x^j} \right)^{-1/\varepsilon} \quad (19)$$

According to this equation, the international terms of trade depend on relative productivity levels and relative employment in the tradables sector.

Labor is not internationally mobile. The supply of labor L therefore equals total demand for labor in each economy $L_Y^i + L_x^i + L_R^i$. Eliminating L_R using (13) and $h=\bar{h}$, we may write labor market equilibrium as:

$$L_Y^i + L_x^i + \frac{(\bar{h}^i/h^i)}{\xi(\bar{h}^i/h^j)^{-\alpha_f}} = L. \quad (20)$$

In the market for foreign exchange, net exports $X^i p^i - \sigma C^i p_c^i$ plus interest receipts on net foreign assets rA^i have to be matched by investments in net foreign assets \dot{A}^i .

$$X^i p^i - \sigma C^i p_c^i + r A^i = \dot{A}^i. \quad (21)$$

Substituting (12) and dividing both sides by $w=hp(\varepsilon-1)/\varepsilon$, see (14), we find:

$$\frac{\varepsilon}{\varepsilon-1} L_x^i - \sigma \left(\frac{\varepsilon}{\varepsilon-1} \right) \frac{C^i p_c^i}{h^i p^i} = \left(\frac{\dot{A}^i}{A^i} - r \right) \frac{A^i}{w^i}. \quad (22)$$

Finally, equilibrium in the market for foreign bonds implies that nominal foreign assets at home equal nominal foreign debt abroad:

$$A^i = -A^j. \quad (23)$$

3. Foreign debt and technological leadership in the long run.

We study the determinants of long-run productivity differences between the two countries and the long-run growth rate. The inherited long-run stock of real foreign asset holdings turns out to be a major determinant. We therefore first derive the international productivity differential that is consistent with a given level of assets holdings in the long run. We thus obtain a relationship between long-run relative productivity and asset holdings. Only thereafter, in section 4, we solve for long-run real asset holdings which requires solving for the entire transition dynamics.

3.1. Steady state equilibria

A steady state is defined by a fixed allocation of labor among the various activities and

constant growth rates. The investment equation (17) reveals that in a steady state the relative knowledge stock h^i/h^j must be constant, that is, that the productivity levels in the domestic and foreign tradables sector grow at a common rate, $\dot{h}^i/h^i = \dot{h}^j/h^j$. We denote this common rate by g . This balanced growth path solution exists and is characterized by⁶

$$g = \frac{\dot{h}^i}{h^i} = \frac{\dot{X}^i}{X^i} = \frac{1}{\sigma} \frac{\dot{C}^i}{C^i} \quad (24)$$

$$= \left(\frac{\dot{w}^i}{w^i} - \frac{\dot{p}^i}{p^i} \right) = \left(\frac{\dot{p}_Y^i}{p_Y^i} - \frac{\dot{p}^i}{p^i} \right) = \frac{1}{1-\sigma} \left(\frac{\dot{p}_c^i}{p_c^i} - \frac{\dot{p}^i}{p^i} \right) = \left(\frac{\dot{A}^i}{A^i} - \frac{\dot{p}^i}{p^i} \right),$$

and

$$\frac{\dot{p}^i}{p^i} - \frac{\dot{p}^j}{p^j} = 0. \quad (25)$$

We can now examine how long-run growth g and relative productivity h^i/h^j are related to net foreign assets. First, we consider equilibrium in the capital market by eliminating r between (4) and (17). The rate of return that consumers require on their savings, see (4), equals the realized rate of return given by (17). In the steady state, this capital market equilibrium condition can be written as:

$$\xi (h^j/h^i)^{\alpha_f} L_x^i = \vartheta + (\alpha_f + \alpha_h)g. \quad (26)$$

Second, we characterize feasible growth as constrained by the labor market and

the balance of payments by combining (20) and (22). After substitution of (4), (18), and (24) this results in the following steady state relationship:

$$g = \xi (h^j/h^i)^{\alpha_f} \left(L - \frac{1-\sigma}{\sigma} \vartheta \frac{A^i}{w^i} - \frac{L_x^i}{\beta} \right), \quad (27)$$

where $\beta \equiv \left(\frac{\varepsilon}{\varepsilon-1} \frac{1-\sigma}{\sigma} + 1 \right)^{-1}$.

The relation between foreign assets, productivity and growth can now be found by eliminating L_x between (26) and (27), which gives:

$$g = \frac{\beta \xi}{\alpha_h + \alpha_f + \beta} \left(\frac{h^i}{h^j} \right)^{-\alpha_f} \left[L - \frac{1-\sigma}{\sigma} \vartheta \frac{A^i}{w^i} \right] - \frac{\vartheta}{\alpha_h + \alpha_f + \beta}. \quad (28)$$

Equation (28) reveals that, for a given growth rate, productivity is negatively related to real net foreign assets. To solve for the growth rate, we take into account the interdependency between the two countries. In particular, we use the fact that the growth rates in both countries as expressed in (28) converge in the steady state, the condition that one's debt is the other's wealth, see (23), and the following expression for relative wages derived from (14), (19), and (26):

$$\frac{w^i}{w^j} = \left(\frac{h^i}{h^j} \right)^{(\varepsilon-1-2\alpha_f)/\varepsilon} \quad (29)$$

Combining (23), (28) and (29), we find:

$$\left(\frac{h^1}{h^2} \right)^{-\alpha_f} \left[L - \frac{1-\sigma}{\sigma} \vartheta \frac{A^1}{w^1} \right] = \left(\frac{h^1}{h^2} \right)^{\alpha_f} \left[L + \frac{1-\sigma}{\sigma} \vartheta \frac{A^1}{w^1} \left(\frac{h^1}{h^2} \right)^{(\varepsilon-1-2\alpha_f)/\varepsilon} \right]. \quad (30)$$

3.2. Catching-up and overtaking

The equality in (30) characterizes the relationship between country 1's real foreign assets A^1/w^1 and the productivity ratio h^1/h^2 . Without international assets ($A=0$) or without non-tradables ($\sigma=1$), productivity levels completely converge. However, a country that lends and has a taste for non-tradables is being overtaken by the rest of the world. This can be checked by plotting the LHS and RHS of (30) against the productivity gap, as in Figure 1 left panel. The lines are downward and upward sloping respectively. For $A^1=0$, the intersection is at $h^1/h^2=1$. Raising A^1 to a positive number shifts the curves down and up respectively and the new intersection is at $h^1/h^2<1$, see the broken lines in Figure 1, left panel. We summarize our results in the right panel: net foreign assets and long-run relative productivity levels are negatively related, that is, productivity levels in rentier economies fall behind those in debtor countries.

Insert Fig. 1

Long-run productivity gaps are driven by two basic forces. First, countries that lag behind benefit relatively more from foreign spillovers which allows them to catch up. Second, spending on non-tradables retards growth because it requires a reallocation of labour from research to non-tradables production.

To illustrate the catch-up potential, we may rewrite (13), taking into account $h^i=\bar{h}^i$, as:

$$\frac{\dot{h}^i}{h^i} = R^i L_R^i, \quad (31)$$

$$\text{where } R^i = \xi (h^i/h^j)^{-\alpha_f}. \quad (32)$$

The productivity of R&D employment, R^i , depends on the ratio of knowledge levels or productivity ratio. A country with relatively low productivity ($h^i/h^j < 1$) benefits from relatively more international spillovers and therefore realizes a higher growth rate for a given amount of labor in R&D.⁷ Note that from the perspective of a single country, diminishing returns apply to the accumulation of knowledge which results in convergence of domestic growth rates to foreign growth rates.

If non-tradables do not play a role, also productivity *levels* converge. Without non-tradables ($\sigma=1$), the steady state level of h^1/h^2 is unity regardless foreign asset positions, see (30). Suppose $\sigma=1$ and consider a hypothetical steady state in which country 1 has lower productivity than country 2. The former would charge higher prices, sell less, and employ less labor in production than the latter. As a result, growth would be faster in country 1 than in country 2 because it has higher research productivity (R) and more labor available for research ($L_R = L - L_x$). But unequal growth rates imply that the situation cannot be a steady state: without non-tradables, catch-up wipes out long-run productivity differences.

To understand the role of non-tradables, allow again for non-tradables ($\sigma < 1$) and note from Figure 1 that the country that ends up with lowest productivity in tradables production is the wealthiest country in terms of foreign assets. Foreign wealth implies income from interest receipts which is partly spent on non-tradables. The wealthy country allocates relatively more labor to non-tradables production than the debtor country and has less labor available for production and research in the tradables sector. Yet, in the steady state, the country grows at the same rate as the (indebted) high

productivity country since lower research labor input (L_R) is offset by higher research productivity (R), see (31) and (32). In other words, large foreign bonds holdings account for abundant consumption, high demand for non-tradables and a shift of labor out of the investment sector, resulting in a relatively lower level of productivity in tradables production, compared to the rest of the world that is indebted.

The model thus predicts that rentier economies that are less open in the sense of having a larger non-tradables sector, suffer a lower productivity level. The role of sheltered sectors may indeed be a plausible explanation behind the productivity demise of wealthy countries in history. As noted in the introduction, housing and construction works, performing arts and other parts of national culture, all to be interpreted as non-tradables sectors, typically flourish in these countries. In terms of Figure 1, right panel, a lower degree of openness (smaller σ) implies a steeper curve depicting the relationship between net foreign asset position and productivity gap. The other way around, a more open world economy exhibits smaller productivity imbalances for given real international debt levels.

3.3. Growth and the international distribution of wealth

Apart from affecting productivity *levels*, the international distribution of wealth (represented by A) affects the world *growth* rate of productivity g . When the distribution is perfectly egalitarian ($A=0$), or equivalently, in the absence of capital mobility, growth equals the following expression which is found by setting h^i/h^j equal to unity in (28):

$$\bar{g} = \frac{\beta \xi L - \mathfrak{d}}{\alpha_h + \alpha_f + \beta}. \quad (33)$$

With foreign assets, growth is either lower or higher than this level \bar{g} , depending upon the parameters of the model. For given levels of real asset holdings, (30) gives the solution for the productivity gap which can be substituted into (28) to solve for the growth rate. In Appendix I, we show that international assets reduce growth, that is $g < \bar{g}$, if $\varepsilon - 1 > 2\alpha_f$, but that the opposite result, $g > \bar{g}$, requires $\varepsilon - 1 < 2\alpha_f$ as a necessary condition. Hence, world growth is retarded by international lending if tradables are close substitutes and international knowledge spillovers are weak. In Figure 2 these results are illustrated for $\alpha_f = 0.25$ and different values of ε .⁸

insert Figure 2

The intuition is as follows. International lending results in relatively high productivity levels, higher research intensity (L_R), but lower researcher's productivity (R) in the debtor country than in the lending country. Thus, a steady state situation arises in which the country with lowest labor productivity in R&D employs most researchers. This is clearly an inefficient distribution of world R&D activity and tends to lower the growth rate.

However, if international spillovers are important, world growth may benefit from a country investing a lot in R&D. Indeed, if $2\alpha_f > \varepsilon - 1$, growth may be positively related to world imbalances in financial wealth. If ε is small, the debtor country suffers from a large terms of trade decline associated with its technological lead. A large shift in labor allocation from non-tradables to tradables is needed to generate sufficient export earnings to service its debt. International knowledge spillovers also have adverse effects on the debtor country's income. If α_f is high, it is difficult to improve its competitive position

since any increase in national productivity also benefits foreign producers. Hence, if ε is small relative to α_p , the debtor country is forced to invest substantially in knowledge accumulation and the creditor country is able to increase non-tradables consumption without adverse effects on its growth rate. Both forces lead to a higher world growth rate.

4. Dynamics

Up to now we have considered the long-run net foreign asset position as given. In Appendix II, we formally show that the long-run net foreign asset position, and hence the long-run productivity gap, depend on the initial productivity gap. Countries that open up to international capital markets when they are ahead of other countries start lending, since the rate of return abroad is higher. In the other country with relatively low domestic stocks of knowledge, there is more scope for learning through international spillovers. Technological catching-up is followed by overtaking, while foreign assets are accumulated by the initially more productive country. Figure 3 illustrates this dynamic process. First, consider the initial situation at point S, with country 1 being the leading country. The world economy converges along SE to point E, with assets being accumulated and the productivity lead shrinking and finally lost in country 1.

Insert Fig. 3

Next, consider the situation in which the leader country starts more ahead, say in point S'. It ends up lending more and losing more in terms of productivity in the long run, as is

illustrated by the path from S' to E' . Hence the model features path-dependency. A formal characterization of path-dependency, as well as the proof that the long-run equilibrium is saddlepoint stable, is provided in Appendix II. In contrast, in the absence of international capital mobility, there is convergence along the vertical axis to the point where $h^1/h^2 = 1$ irrespective of whether the economy starts at S or S' . Hence, no path-dependency applies under balanced trade.

The numerical example in Table 1 gives some insights in what is going on during the process of overtaking. The upper part of the table reports the percentage by which a certain key variable in country 1 differs from that in country 2. For example, consumption in country 1 at time 0 is 0.257 % higher than in country 2. Real asset holdings are reported for country 1 (A^1/w^1) in absolute magnitude. Only results for time 0 and the steady state are reported since there is a monotonic convergence towards the steady state. The speed of convergence is reported in the last row of the table. All calculations are based on a log-linearization of the model, as described in Appendix II. The parameters used are reported in the table.

insert Table 1

We assume that on $t = 0$, the world economy starts with zero international assets and an initial productivity level in tradables that is 1 % higher in country 1 than in country 2. In the long run, productivity in country 1 falls behind the other country's productivity by 0.386 percent. During the transition process, country 1 grows at a slower rate than its trading partner, but in the end growth rates converge. Initially, the fast growing country employs less labor in production of tradables thus freeing up labor for

research activities. Initially low home production of tradables in this country allows for net foreign exports of tradables by country 1 that therefore accumulates net foreign assets. Country 1 starts with low spending on non-tradables (thus freeing up labor for the export sector), but ends up with a larger non-tradables sector, thus spending the interest receipts on foreign assets on non-tradables. Its tradables sector is smaller in the long run, but interest receipts are used to finance imports of tradables. Note that consumption in the wealthy country exceeds that in the other country over the entire transition.

5. Welfare implications

When capital mobility causes advanced countries to lose their productivity leadership, the natural question arises whether these countries would do better by restricting capital outflows. Before analyzing this question, it should be noted that welfare and productivity are not necessarily moving in the same direction. Compared to the debtor country, the wealthy country has lower productivity but also has higher income from its foreign assets. Indeed, consumption levels in the wealthy country are higher than in the other country over the entire horizon (cf. Table 1), so that overtaking is in terms of productivity but not in terms of welfare (as in Brezis and Tsiddon, 1998).

Nevertheless, welfare in the absence of international asset trade may be higher than under capital mobility. Capital mobility affects welfare through three important channels in the model. First, it allows funds to flow to the most profitable investment projects and increases the scope for consumption smoothing. International adjustment is thus speeded up. This conventional effect raises overall welfare (that is, the sum of

welfare over the two countries). Second, capital mobility affects the long-run growth rate and therefore also welfare. As discussed in section 3, this effect depends on the balance between the degree of monopoly power (ϵ) and foreign spillover (α_f), which are the two distortions in the model that may impair the conventional welfare raising effect of capital mobility. Third, knowledge spillovers between two countries affect the distribution of welfare over the two countries. Domestic knowledge spillovers imply underinvestment from a welfare point of view. Since capital mobility speeds up investment in the initially lagging country and slows down investment in the other country, capital mobility mitigates this underinvestment effect in the former country, but aggravates it in the latter. Cross-country spillovers have an opposite effect. The returns to innovation accrue partly to the trading partner, thereby deteriorating the own competitive position. Hence, foreign spillovers result in overinvestment from the view point of national welfare. Capital mobility aggravates overinvestment in the initially lagging country. The final result on welfare depends on the parameters of the model.

While the welfare gains of capital mobility may be impaired through externalities, there is no reason to restrict capital flows. From a national perspective, the first-best policy is to address the spillover externalities by a subsidy or tax to R&D (depending on whether there is overinvestment or underinvestment) and to address the product market distortion by appropriately subsidizing monopolistic producers. Maximization of world welfare levels requires that the policies of the two countries are appropriately coordinated.

6. Conclusions

We have shown that the combination of home-bound accumulation of technology, tastes for non-tradables, and international capital mobility produces a dynamic process by which an initially leading country invests in the backward country and is ultimately being overtaken in terms of productivity levels. The results place the convergence literature in a different perspective. Long-run growth of the global economy as well as relative cross-country productivity levels are path-dependent and depend on the initial distribution of financial wealth across countries. International financial market institutions matter not only for the speed of convergence but also for the long-run distribution of productivity. The openness of the economy, as measured by the relative size of the tradables sector, plays a key role in the processes of convergence and leapfrogging.

Appendix I. A sufficient condition for g declining in $|A/w|$

From (28) and (30), we derive by total differentiating:

$$\frac{dg}{da_w} \begin{matrix} \geq \\ \leq \end{matrix} 0 \quad \Leftrightarrow \quad \frac{\alpha_f \left[1 + (h^r)^{2\alpha_f + \psi} \right]}{2\alpha_f + (h^r)^\psi \psi a_w B} \begin{matrix} \leq \\ \geq \end{matrix} 1$$

where

$$h^r \equiv h^1/h^2, \quad a_w \equiv A^1/w^1,$$

$$\psi \equiv (\varepsilon - 1 - 2\alpha_f)/\varepsilon,$$

$$B \equiv \frac{(1-\sigma)\vartheta}{\sigma L + (h^r)^\psi (1-\sigma)\vartheta a_w} = \frac{1-\sigma}{\sigma} \vartheta (h^r)^{\alpha_f} \left(\frac{\beta}{\vartheta + (\beta + \alpha_f + \alpha_h)g} \right) > 0.$$

Now we make use of the fact that h^r and a_w are negatively related and that symmetry ($h^r=1$) obtains if net foreign assets are zero ($a_w=0$). If $\varepsilon-1>2\alpha_f$, then $\psi>0$ and

$$h^r = 1 \quad \wedge \quad a_w = 0 \quad \Rightarrow \quad \frac{dg}{da_w} = 0,$$

$$h^r > 1 \quad \wedge \quad a_w < 0 \quad \Rightarrow \quad \frac{dg}{da_w} < 0,$$

$$h^r < 1 \quad \wedge \quad a_w > 0 \quad \Rightarrow \quad \frac{dg}{da_w} < 0.$$

Hence, $a_w=0$ yields a maximum for g if $\varepsilon-1>2\alpha_f$.

Appendix II Hysteresis and stability

This appendix briefly explores the dynamics of the model. We show that it is (locally) saddlepoint stable and that it features path-dependency.

Since most variables of the model are non-stationary and growing at an endogenously determined rate in the steady state, see (24), we study the dynamics of *ratios* of variables. Since in the steady state a particular variable grows at the same rate in both countries, the ratio of a variable in country 1 relative to that in country 2 is stationary. We therefore define for any variable x the stationary ratio $x^r \equiv x^1/x^2$.

From (4), (6), (11), (14), and (21) we find:

$$\dot{C}^r/C^r = (\sigma-1)(\dot{h}^r/h^r + \dot{p}^r/p^r)$$

Integrating this relationship we find:

$$C^r = (h^r p^r)^{\sigma-1} v \quad (\text{A.1})$$

where v is a constant of integration that has to be determined endogenously. We will show that this constant depends on the initial value of the state variable h^r , which implies that the model exhibits hysteresis. We need to know the entire transition dynamics to solve for the steady state.

We now reduce the model to a three-dimensional dynamic system. First, we log-linearize all equations around the steady state in case of symmetry ($h^1/h^2 = 1$, $A = 0$). We use tildes to denote percentage deviations from initial steady state values: $\tilde{x} \equiv d \ln x$. In the sequel, symbols without a tilde relate to symmetric steady state values. Secondly, we subtract equations such that the entire model is written in ratios $\tilde{x}^r = d \ln x^r = \tilde{x}^1 - \tilde{x}^2$. The only exception relates to net foreign assets.⁹ We define $a_w^{-1} \equiv A^1/w^1$ and $\tilde{a}_w^{-1} \equiv d a_w^{-1}$. Following this two-step procedure, we can derive the following system of three linear differential equations:

$$\begin{bmatrix} \dot{\tilde{h}}^r(t) \\ \dot{\tilde{p}}^r(t) \\ \dot{\tilde{a}}_w^{-1}(t) \end{bmatrix} = \begin{bmatrix} \mu_{11} & \mu_{12} & 0 \\ \mu_{21} & \mu_{22} & 0 \\ 0 & \mu_{32} & \vartheta \end{bmatrix} \begin{bmatrix} \tilde{h}^r(t) \\ \tilde{p}^r(t) \\ \tilde{a}_w^{-1}(t) \end{bmatrix} - \begin{bmatrix} \xi L_Y \\ \xi L_Y (\alpha_h - \alpha_f - 1) \\ \mu_{34} \end{bmatrix} \tilde{v} \quad (\text{A.2})$$

where

$$\mu_{11} = \xi L_x + \xi L_Y - 2\alpha_f g$$

$$\mu_{12} = \xi \varepsilon L_x + \xi L_Y > 0$$

$$\mu_{21} = (\alpha_h - \alpha_f)\mu_{11} - \xi L_Y + 2\alpha_f(\xi L_x + g)$$

$$\mu_{22} = (\alpha_h - \alpha_f)\mu_{12} - \xi L_Y$$

$$\mu_{32} = -(L_x/2)\varepsilon$$

$$\mu_{34} = (L_x/2)\varepsilon/(\varepsilon - 1)$$

and where all variables with a tilde depend on the time index t . Note that $\tilde{h}^r(t)$ and $\tilde{a}_w^{-1}(t)$ are predetermined, while $\tilde{p}^r(t)$ jumps at time $t = 0$. The sub-system in $\tilde{h}^r(t)$ and $\tilde{p}^r(t)$ is self-contained and saddlepoint stable if the determinant of the relevant matrix (Δ) is negative.

From (A.2) we find:

$$\Delta = \xi L_x [(\varepsilon - 1 - 2\alpha_f)\xi L_Y - 2\alpha_f\varepsilon(\xi L_x + g)] \quad (\text{A.3})$$

It will be assumed that $\Delta < 0$. A sufficient condition for this to hold is: $(\varepsilon - 1 - 2\alpha_f) < 0$.

More in general, the determinant will be negative for sufficiently small values of L_Y . If the non-tradables sector is non-existent, we always have saddlepoint stability.

The first two differential equations can be used to solve for $\tilde{h}^r(t)$ and $\tilde{p}^r(t)$ in terms of \tilde{v} and $\tilde{h}^r(0)$. This yields:

$$\tilde{h}^r(t) = (1 - e^{-\lambda t})\tilde{h}^r(0) + e^{-\lambda t}\tilde{h}^r(\infty), \quad (\text{A.4})$$

$$\tilde{h}^r(\infty) = -\left(\frac{\varepsilon}{-\Delta/\xi L_x}\right)\xi L_Y \tilde{v}, \quad (\text{A.5})$$

$$\tilde{p}^r(t) = (1 - e^{-\lambda t})\tilde{p}^r(0) + e^{-\lambda t}\tilde{p}^r(\infty), \quad (\text{A.6})$$

$$\tilde{p}^r(\infty) = \left(\frac{1+2\alpha_f}{-\Delta/\xi L_x} \right) \xi L_Y \tilde{v}, \quad (\text{A.7})$$

$$\tilde{p}^r(0) = \frac{\lambda \tilde{p}^r(\infty) - (1-\alpha_h + \alpha_f) \xi L_Y \tilde{v} - \mu_{21} \tilde{h}^r(0)}{\lambda + \mu_{22}}, \quad (\text{A.8})$$

where λ is the absolute value of the negative root of the relevant sub-matrix. Substitution of (A.6) in the third differential equation in (A.2) yields:

$$\tilde{a}_w^1(t) = \mu_{32} \left\{ \tilde{p}^r(\infty) + e^{-\lambda t} [\tilde{p}^r(0) - \tilde{p}^r(\infty)] \right\} + \mathfrak{d} \tilde{a}_w^1(t) - \mu_{34} \tilde{v}. \quad (\text{A.9})$$

This linear differential equation in the state variable \tilde{a} can be solved as

$$\tilde{a}_w^1(t) = \frac{-\mu_{32} [\tilde{p}^r(0) - \tilde{p}^r(\infty)]}{\lambda + \mathfrak{d}} e^{-\lambda t} + \frac{\mu_{34} \tilde{v} - \mu_{32} \tilde{p}^r(\infty)}{\mathfrak{d}} \quad (\text{A.10})$$

The state variable $\tilde{a}_w^1(t)$ is predetermined, so that $\tilde{a}_w^1(0)$ is given. Consequently, by setting $t = 0$ and substituting (A.7) and (A.8), eq. (A.10) can be used to express \tilde{v} in terms of $\tilde{a}_w^1(0)$ and $\tilde{h}^r(0)$.

Summarizing, we find that the long-run solution depends on \tilde{v} , see (A.5), which in turn depends on initial conditions. This clearly points out that the model exhibits hysteresis.

Acknowledgments

We thank two anonymous referees, Lucas Bretschger and Pietro Peretto for useful comments on an earlier draft. All remaining errors are ours.

Smulders' research was financed by the Dutch National Science Foundation NWO.

References

- Abramovitz, M., 1986, Catching-up, Forging Ahead and Falling Behind, *Journal of Economic History* 46, 385-406.
- Barro, R.J., N.G. Mankiw and X. Sala-i-Martin 1995, Capital Mobility in Neoclassical Models of Growth, *American Economic Review* 85, 103-115.
- Barro, R.J. and X. Sala-i-Martin, 1997, Technological Diffusion, Convergence and Growth, *Journal of Economic Growth* 2, 1-26.
- Braudel, F. 1986, *The Perspective of the World, Civilization and Capitalism 15th-18th century* (Harper and Row, New York).
- Brezis, E., 1995, Foreign Capital Flows in the Century of Britain's Industrial Revolution: new estimates, controlled conjectures, *Economic History Review* 48, 46-67.
- Brezis, E., P. Krugman and D. Tsiddon, 'Leapfrogging: a Theory of Cycles in International Technological Leadership', *American Economic Review* 83, 1211-1219.
- Brezis, E. and D. Tsiddon, 1998, Economic Growth, Leadership and Capital Flows, the Leapfrogging Effect, *Journal of International Trade and Economic Development* 7, 261-277.

- Buiter, W.H. and K.M. Kletzer, 1993, Permanent International Productivity Growth Differentials in an Integrated Global Economy, *Scandinavian Journal of Economics* 95, 467-493.
- Buiter, W.H. and K.M. Kletzer, 1995, Capital Mobility, Fiscal Policy and Growth under Self-financing of Human Capital Formation, *Canadian Journal of Economics* 28, special issue, S163-S194.
- Burke, P. 1973, *Venice and Amsterdam, a study of seventeenth-century élites* (Temple Smith, London).
- Feenstra, R., 1996, Trade and Uneven Growth, *Journal of Development Economics* 49, 229-256.
- Grossman, G.M. and E. Helpman, 1991, *Innovation and Growth in the Global Economy* (MIT Press, Cambridge MA).
- Maddison, A., 1991, *Dynamic Forces in Capitalist Development; a Long-run Comparative View* (Oxford University Press, Oxford and New York).
- Oppers, S.E., 1993, The Interest Rate Effect of Dutch Money in Eighteenth-Century Britain, *Journal of Economic History* 52, 25-43.
- Ohyama, M. and R.W. Jones, 1995, Technology choice, overtaking and comparative advantage, *Review of International Economics* 3, 224-234.
- Pareto, V., 1917, *Traité de Sociologie Générale* (Payot, Lausanne/Paris).
- Romer, P.M., 1990, Endogenous Technological Change, *Journal of Political Economy*, 98, s71-s102.
- Schama, S., 1987, *The embarrassment of riches: an interpretation of Dutch culture in the golden age* (Knopf, New York).
- Smulders, J. and Th. van de Klundert, 1995, Imperfect Competition, Concentration and

Growth with Firm-specific R&D, *European Economic Review* 39, 139-160.

Taylor, A.M., 1996, *Convergence and International Factor Flows in Theory and History*, NBER working paper 5798.

Turnovsky, S.J. and P. Sen, 1991, *Fiscal Policy, Capital Accumulation and Debt in an Open Economy*, *Oxford Economic Papers* 43, 1-24.

Van Elkan, R., 1996, *Catching up and Slowing Down: Learning and Growth Patterns in an Open Economy*, *Journal of International Economics* 41, 95-111.

Williamson, J.G., 1964, *American Growth and the Balance of Payments: A Study of the Long Swing* (Duke University Press, Durham and London).

Table 1 The process of catching up and overtaking

Period	$t = 0$	steady state
Variable*		
Productivity	1.000	-0.386
Labor tradables	0.599	-0.193
Labor non-tradables	-0.013	0.502
Productivity growth	-1.831	0.000
Consumption	0.257	0.386
Price tradables	-0.640	0.232
Asset holdings**	0.000	0.868
speed of convergence		4.404%

* Calculations based on log-linearized model, see Appendix II. Parameters: $\hat{v}=0.05$, $\sigma=0.75$, $\varepsilon=2.5$, $\alpha_h=0.5$, $\alpha_f=0.25$, $\xi=0.01$, $L=15$.

** Real asset holdings in country 1, A^1/w^1 . All other numbers represent variables for country 1 expressed as percentage difference relative to country 2.

Legends for Figures

Fig. 1 The long-run productivity gap

Fig. 2 Growth and foreign assets in the steady state

Fig. 3 Dynamics

Footnotes

1. Sociologists have focused on the change in attitudes "from merchants to rentiers" (Burke 1974), or from "entrepreneurs to speculators" (Pareto 1917). They document the almost embarrassing display of wealth in rentier economies (Schama 1987).
2. This may be seen as an indirect manner to capture the idea that economic growth depends also on cultural and social factors.
3. In Buiter and Kletzer (1995) home-boundedness is modeled in a somewhat different way by assuming an imperfect domestic credit market in which it is impossible to borrow for education.
4. Alternatively, C_Y can be interpreted as leisure (cf. Buiter and Kletzer 1993).
5. Note that firm i 's demand equals the sum of domestic sales D^i and exports M^j .
6. The growth rate of X follows from (12), that of C from (2) and (10) (note that $C_Y = Y = L_Y$ is constant along the balanced growth path). The growth rate of real wages follows from (14), and that of the relative price of non-tradables from (11). The growth rate of real consumer prices can be easily derived from (18). Equation (22) reveals that asset holdings A grow at the same rate as wages w in the steady state. Equation (19) reveals that the steady state relative price is constant.

7. Note that h^i/h^j is given by history. Since knowledge is firm-specific, firms have to accumulate their own knowledge which takes time. Firms in countries with high rates of return to investment borrow in the international capital market to finance R&D. Since it takes time to build the firm's knowledge stock, there is no immediate adjustment of international productivity levels.

8. The other parameters used in the numerical exercise are $\vartheta=0.05$, $\sigma=0.75$, $\alpha_h = 0.5$, $\xi=0.015$ and $L=15$. With these parameters we get $g=\bar{g}$ irrespective of the value of A if $\varepsilon = 1.2$.

9. Note from (23) that $A^1(t)/A^2(t) = -1$ so that A^r is not a useful stationary variable, and that $A=0$ in a symmetric steady state so that d/nA is undefined.





